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appointed assistant professor of forestry in the University of California, in the new department of which Walter Mulford, now professor of forestry at Cornell, is next August, to become the head.

DR. ALBERT N. GILBERTSON has charge of the instruction in anthropology at the University of Minnesota in the absence on leave of Dr. A. E. Jenks.

DR. OSCAR PERRON, of Tübingen, has been called to a professorship of mathematics at Heidelberg.

DISCUSSION AND CORRESPONDENCE

WHAT WAS THE CAUSE OF THE ESKERS?

TO THE EDITOR OF SCIENCE: Eskers are features of the earth's surface well known to all students of glacial phenomena. They are more or less well defined ridges composed of mixtures of sand, gravel, clay and boulders, having a direction generally parallel to that of the movement of the latest ice sheet that covered the region where they occur, or normal to the front boundary of the sheet, and they often have a length of many miles, though entire continuity rarely exists throughout the length of any one such ridge or series of ridges having such relations as to be considered as one esker. In some cases such ridges have a striking uniformity in height and cross section, with an abruptness of side slopes and an alignment that suggest an artificial embankment like that for a railroad or a levee. Other forms that have been called eskers are flattened and spread out, broken into detached ridges that often depart from parallelism, and these are frequently associated with knolls and irregular hummocks and valleys that would not be considered as related in any way to esker forms if they stood by themselves. Eskers in the United States have been described and illustrated in several publications of the United States Geological Survey, as well as in various papers and geological text-books. They are numerous and extensive in the eastern part of that portion of North America that was covered by the latest ice sheet, particularly in Maine, New Brunswick and the

eastern Canadian provinces. Several examples on a smaller scale are found in the Great Lakes region of the United States. The writer has examined more especially the eskers near Circleville, south of Norwalk, and near Kenton, in Ohio; the one north of Muncie, Indiana, the fine example near Kaneville, Ill., and the strikingly uniform and conspicuous esker ridge at Mason in southern Michigan. Casual examination has also been made of similar ridges in Ontario, Canada.

The theory to account for these ridges which is most often met with is that they were formed by stream action, in crevices or in tunnels under the ice, during the period of recession or withdrawal of the ice sheet. From the published descriptions and views and sketches of eskers and from the examinations above referred to, I became satisfied that this theory was untenable, although there are some evidences that stream action has had a secondary and modifying effect on the final esker forms in some cases. I concluded that the eskers resulted primarily and principally from cracks in an ice sheet of moderate thickness covering approximately smooth and level areas of considerable extent; these cracks becoming the locus of the accumulation of the esker material from the lateral "shove" of the separated parts of the ice sheet under the influence of seasonal changes of temperature. This action resulted in the upheaval and breaking of the ice along the initial crack, and the melting of the resulting broken ice at a rate greater than that of the main ice sheet due to increase of exposed surfaces, with the accumulation of the general surface earthy material as well as that imprisoned within the ice itself along a more or less well-defined line. This earthy material remained, of course, after the ice disappeared, and it was often modified to a greater or less extent by flowing water during the melting of the ice. I prepared a tentative memorandum setting forth this view some three years or more ago, but it was not published. The illustrated supplement of the *New York Times* of November 23 contains a photographic view of a "pressure ridge" in a sheet

of sea ice, taken from Captain Scott's narrative of his South Pole expedition, which recalls the subject to mind. This picture seems to afford a very decided support for the above theory.

I conceive that the conditions under which eskers were formed were similar to those illustrated by this view of a pressure ridge, although in this case the ridge is understood to have been formed in ice resting on water. It is possible that at the time of the formation of the esker ridges the movement of the ice was facilitated by water underlying the sheet over considerable areas, so that the ice was partially afloat at least for portions of each year.

Very pronounced ridges of boulders and other material are formed under weather conditions now existing around the shores of small interior lakes in cold climates by the "push" of the ice that covers the lakes each winter.

I believe that the seasonal variations in temperature that must have occurred even during the low average temperature of the glacial period, with resulting changes in the internal structure and movements of the ice, constituted an influence of more importance in connection with general glacial phenomena than has heretofore been recognized.

The "trough" or depression along one or both sides of the ridge which sometimes occurs as a marked feature in connection with an esker was probably due primarily to the greater scooping and shoving effects of the ice on the underlying earth material immediately adjacent to the ridge, on account of the broken condition of the ice and the increased weight resulting from increased thickness and the superimposed broken blocks and fragments. The esker ridge itself and such side depressions would sometimes determine or materially modify the immediate post-glacial drainage of the locality, when the depressions would become still further emphasized by stream erosion during and after the melting of the ice. Furthermore, the "delta formation" sometimes found near the end of the esker is thus explained.

A theory similar to the above is applicable to certain irregular detached groups of knolls

or hummocks and short ridges with intervening troughs and hollows, called *kame* areas. Some examples of these may mark a sort of focus for the lateral shove from various directions of the surrounding ice sheet. In at least one locality that has been studied in considerable detail the assumption of the formation of an interglacial ridge by a process similar to that described above, but with a direction transverse to that of the general movement of the ice sheet, seems to afford a clue to an explanation of several surface features of the vicinity, and possibly this may also apply to some special cases where there has been difficulty in fitting the terminal moraine theory with entire satisfaction.

The probability of an extensive ice sheet of moderate thickness in comparison with that of earlier ice "invasions" of the same area, and as the final stage of the glacial period for the region in question, suggests other interesting deductions in connection with the causes of present surface forms.

JOHN MILLIS

November 25, 1913

MATTER AND MEMORY

ON reading with interest the article of Professor R. D. Carmichael, *SCIENCE*, December 19, I find on page 869 a statement which can not pass as entirely general: "... mind ... has chosen to assume that matter is without memory."

While in abstract reasoning we prefer to assume that matter has no memory, nevertheless we well know that in all too many cases this assumption is made for simplicity, not for exactness. The existence of zero drift, permanent set, elastic, magnetic and dielectric hysteresis, etc., so complicates the actual conditions, by making them dependent on the previous experiences of the material under consideration, that we can not set up ideally exact general equations. The complications are by no means as overwhelming as those, for example, which present themselves in dealing with warm-blooded animals, but they are real. What the instrument-maker desires is matter which does forget, whether he be interested in galvanometer suspensions or transformer cores. To speak figuratively, the suspension "re-